EXECUTIVE SUMMARY

Description/Background of Project:

In 1999, thirty homes in the Wissinoming section of Philadelphia were condemned because of severe settlement of their foundations. The homes lie in the square block bordered by Vandike Street on the north, Hegerman Street on the south, Benner Street on the west, and Devereaux Avenue on the east. These homes were apparently built on loosely compacted, miscellaneous fill comprised of ash and cinders mixed with varying amounts of construction debris, such as wood and brick, and soil which was used to fill in the historic Wissinoming Creek bed. The subsidence problems which occurred can arise from a variety of factors – the type of fill used (in this case ash/cinder as opposed to soil), the amount of compaction performed during the installation, and subsequent exposure to water from utility leaks or other causes. The City of Philadelphia, through Senator Specter, Senator Santorum, and Representative Borski, has requested the assistance of the US Army Corps of Engineers to investigate the problem.

Scope of the Engineering Study:

The focus of the project was to gather and develop data to perform a preliminary analysis of the potential magnitude, extent, and scope of the problem and its possible causes. The study area lies in a portion of the Wissinoming basin, an approximately three-square-mile region where various filled-in tributaries drained into the Wissinoming Creek. The US Army Corps of Engineers (USACE) defined the horizontal and vertical extent of the original creek bed. A topographic change map has been prepared to show the distribution of fill by measuring topographical changes from a century ago. Limited geophysical investigations were performed in the basin to verify the location of the fill, characterize the soil conditions, and help ascertain the accuracy of the topographic change map. Also, a cursory building exterior assessment was performed to identify any structures that were in imminent danger of failure, settlement and its correlation to the depth of fill, or if any structures had signs of continuing rapid settlement/movement. Lateral inspections have been performed on two homes which were adjacent to the demolished homes on Vandike and Hegerman Streets. Finally, drawings of water, gas, and sewer mains have been obtained from the City in various formats, including hard copy and georeferenced digital images. Digital images of sewer lines have been incorporated into Geographic Information Systems (GIS) applications to support future investigations of these lines and their correlation to subsidence problems. This study presents findings and provides recommendations for more comprehensive studies required to design remediation efforts.

Funding:

This is an environmental assistance project authorized by the Southeastern Pennsylvania Environmental Assistance Program, Section 566 of the Water Resources Development Act (WRDA) of 1996. Funding in the amount of $150,000 has been authorized to complete this initial engineering study.

This initial engineering study presents preliminary findings only and future reports, inspections, design, and/or construction under the Section 566 authority (Appendix E) would require a non-Federal Sponsor (City of Philadelphia, for example) who understands and is willing to participate in the cost sharing (75% Federal, 25% non-Federal) of such efforts. Future work to be accomplished under this authority would be limited to publicly owned facilities that would be in compliance with the implementation guidance established for Section 566 (water-related projects). Funding of studies and projects under Section 566 authority is presently a low budgetary priority.

Findings:

The topographic change map completed by the USACE provided surface elevation changes for the Wissinoming Creek downstream of Frankford Avenue. The map assists in defining the depth and extent of the fill and assisted in focusing the areas of investigation for further subsurface and building assessment investigations.

The USACE map utilized detailed pre-development topography on which to base a higher resolution investigation of surface elevation changes to produce maps which show the possible or probable depth of fill. This was accomplished with the City of Philadelphia Streets Department maps which showed five-foot contour intervals dating back to approximately 1888.

Based on the results of previous and current investigations, it appears that the former Wissinoming Creek has been filled in with a combination of “common” and miscellaneous fill. Within the area were the rowhouses were condemned and razed, the “common” fill ranges in thickness from 9 to 24 feet and is comprised of layers of sands, silts, clays and organics. The miscellaneous fill is comprised of ash and cinders mixed with varying amounts of construction debris, such as wood and brick, and soil. Because of the low penetration resistance, this fill appears not to have been properly compacted (to today’s standards). Combined with the exterior structural investigation conducted, it appears that the majority of the settlement exhibited by the residences in the Wissinoming Section is due to the settlement of the granular materials used to fill in the former creek. No physical testing or chemical sampling was performed for this investigation.

The presence of water in the loosely compacted fill material can lead to additional settlement beyond that which occurs immediately. The lowering of the groundwater table, which can happen either naturally over time or by methods such as pumping (dewatering operations), increases the amount of settlement that can occur. The rising of the groundwater table can also affect loose, granular material by allowing the soil particles to settle. Subsurface erosion due to the flow of the groundwater and/or the introduction of water from house laterals or street sewers could possibly occur.

The building exterior assessments revealed that all of the structures visually inspected currently appear in stable condition. There was no evidence of continuing settlement. The structures south of Torresdale Avenue on Vandike Street and Hegerman Street showed more signs of distress from settlement along entire rows of structures, while the structures north of Torresdale Avenue showed signs of distress from settlement at the end units of rows of structures. At some locations, downspouts were adjacent to walls that appear to have settled, but that they were the direct cause of settlement can not be definitely concluded without further investigation.

Broken and misaligned laterals can contribute to differential settlement which may have significant impacts on the structural integrity of a building. However, an examination of the original brick and mortar sewer on Vandike Street between Benner Street and Devereaux Avenue and a portion of the newly installed sewer on Hegerman Street did not reveal any structural defects.

Recommendations:

Based on the results of this study, the following recommendations are provided to monitor/minimize the likelihood of a future subsidence problem:

- Utilizing Philadelphia Streets Department data, analyze and provide more detailed, localized depth of fill maps for all of Wissinoming to include completion of data digitization for water, gas, and sewer. The cost estimate to complete this effort is approximately $30,000 total with an estimated six month time period.

- City of Philadelphia should ensure that foundation design criteria, for new structures built within the fill zones, requires that the buildings be founded on suitable ground.

- During the replacement or repair of any utilities in the Wissinoming neighborhood that may be founded on fill material, the City of Philadelphia should ensure that the utilities are set and backfilled with compacted structural fill.

- Perform an inventory of the structures that show signs of distress caused by settlement within the fill area.

- Perform a semi-annual or annual inspection to update or supplement the inventory. Any structures showing signs of continuing or rapid change should be inspected more thoroughly, including interior foundation walls

- Establish a telephone number for residents to call if they notice changes in their particular structures.

- Establish a standard procedure for which a detailed structural inventory would be performed and damage prevention measures would be instituted at locations where construction activities (i.e., deep excavations, dewatering, pile driving, fill compaction etc.) are undertaken that might disturb the fill or could impact structural integrity of homes. This would include proper design of construction methods which are to be utilized in the areas of fill.

- Proper design of future construction methods/work which could impact structural integrity of homes built on fill.

- Establish survey reference points on the structures that have show the most signs of settlement, particular the structure at the end of rows, and monitor the movement annually by field survey.

- Philadelphia Water Department to inspect sewer and water infrastructure in areas of fill to verify integrity; repair if necessary. The cost estimate to complete the inspection of the infrastructure is approximately $195,000 total with an estimated six month or more time period, depending on the level of effort. Design and construction costs would later be based on the results of the inspection.

- Inspect homeowner laterals in areas of fill to ensure integrity/proper drainage utilizing video and dye test techniques; repair and replace as necessary with PVC piping.

- Inspect homeowner rainwater conductors to ensure integrity/proper drainage; repair and replace as necessary.

- Remove large trees from sidewalks which could be impacting sewer/lateral integrity; replace with a variety less conducive of damage.

- The unique phenomenon of sinking homes, resulting from decades of inconspicuous subsidence, poses a dilemma for effective government intervention. Smaller governments have difficulty bearing the burden of the corresponding monetary responsibilities required to address such disasters which, in this instance, involved the condemnation of homes and relocation of residents. Most homeowners' insurance policies do not cover subsidence-related problems. A more prudent approach by government would be to utilize investigative/preventative measures to minimize or eliminate such occurrences. The fact that this particular problem is rooted to historic, diverted creeks and streams, however, tends to associate the issue to a water-related infrastructure project eligible for assistance under Southeastern Pennsylvania Environmental Assistance Program, Section 566 of the WRDA.

SECTION 2.0
DESCRIPTION/BACKGROUND OF PROJECT

2.1 Study Area

The Wissinoming neighborhood is a small community located in the Near Northeast section of Philadelphia. It is an area of approximately one square mile, bounded by the area between the Delaware River to Frankford Avenue, Cheltenham Avenue to Magee Avenue. Wissinoming is a Lenape Indian place name which many historians have pondered, but which none has definitely solved. Some have suggested it means “the place of wild grapes” and others “the place where we were frightened.” A possible explanation is found in the fact the Indian name of the present Tacony creek was Quessinawomink, and the history of Tacony and Wissinoming is intimately associated and interwoven. The alternate spelling of this name is Kwissinomink, which would be pronounced Wissinoming in English and possibly mean Duck Creek.

Prior to the 1920’s, the area was mostly open fields, stream valleys, and farms. It was the site of summer homes for the affluent of Center City. The area lies within the Wissinoming basin, an approximately three-square-mile region where various filled-in tributaries drained into the Wissinoming Creek. At the turn of the century, however, plans were drawn to reroute the creek through brick and mortar encased sewers. The stream valley was then filled with varying natural/artificial materials. This included either soil which was moved from higher ground or, coal ash/cinder which was an abundant byproduct of homes and industry during the period. This practice became common throughout the region after the Civil War, as Philadelphia’s labyrinth of stream and creek valleys hampered development and progress.

After that, streets were laid out and the community grew and developed with the introduction of the trolley car and automobile which enabled people to travel longer distances from their homes to work. It allowed them to escape the pollution of the factories in which they worked. Most people also moved here for a larger home with grass or small gardens around it as well as more open space than in the old city neighborhoods. For the most part, the streets of Wissinoming are quiet and tree-decorated. About two-thirds of the homes were built before 1939. The section north of Cheltenham Avenue up to Devereaux Avenue is an older area with fairly large 2- and 3-story singles and twins of brick and frame with separate garages, and two story brick rows with porches. North of Devereaux Avenue is mostly newer brick-faced cinder block or brick two story rows with interior garages.

Modern expansion, however, was not without its problems. Some homes which were built on the filled-in Wissinoming creek bed began to exhibit settlement cracks. Several incidences throughout the last century have occurred in which a street or home have sunk into a collapsed sewer which has been undermined by water or adverse loads imposed by increasing traffic and development. On other occasions, homes began to settle into the unstable/uncompacted fill on which the homes were built.

In June 1999, thirty homes in the Wissinoming neighborhood were condemned and eventually demolished because of severe structural distress resulting from the settlement of their foundations. The homes lie in the portion of Wissinoming bordered by Vandike Street on the north, Hegerman Street on the south, Benner Street on the west, and Devereaux Avenue on the east. At the time, residents were concerned that the settlement of the homes was accelerated by a City of Philadelphia water and sewer project on Hegerman Street in 1996. The combination sewer installed during the construction was a 72-inch diameter, reinforced concrete pipe which was buried approximately 18 feet deep. An independent consultant, hired by attorneys representing the residents, concluded that dewatering operations during the installation of the new sewer and water main resulted in additional settlement. During the dewatering process, the groundwater table was lowered which resulted in an increase in stress imposed on the soil by the foundation, thereby increasing settlement.

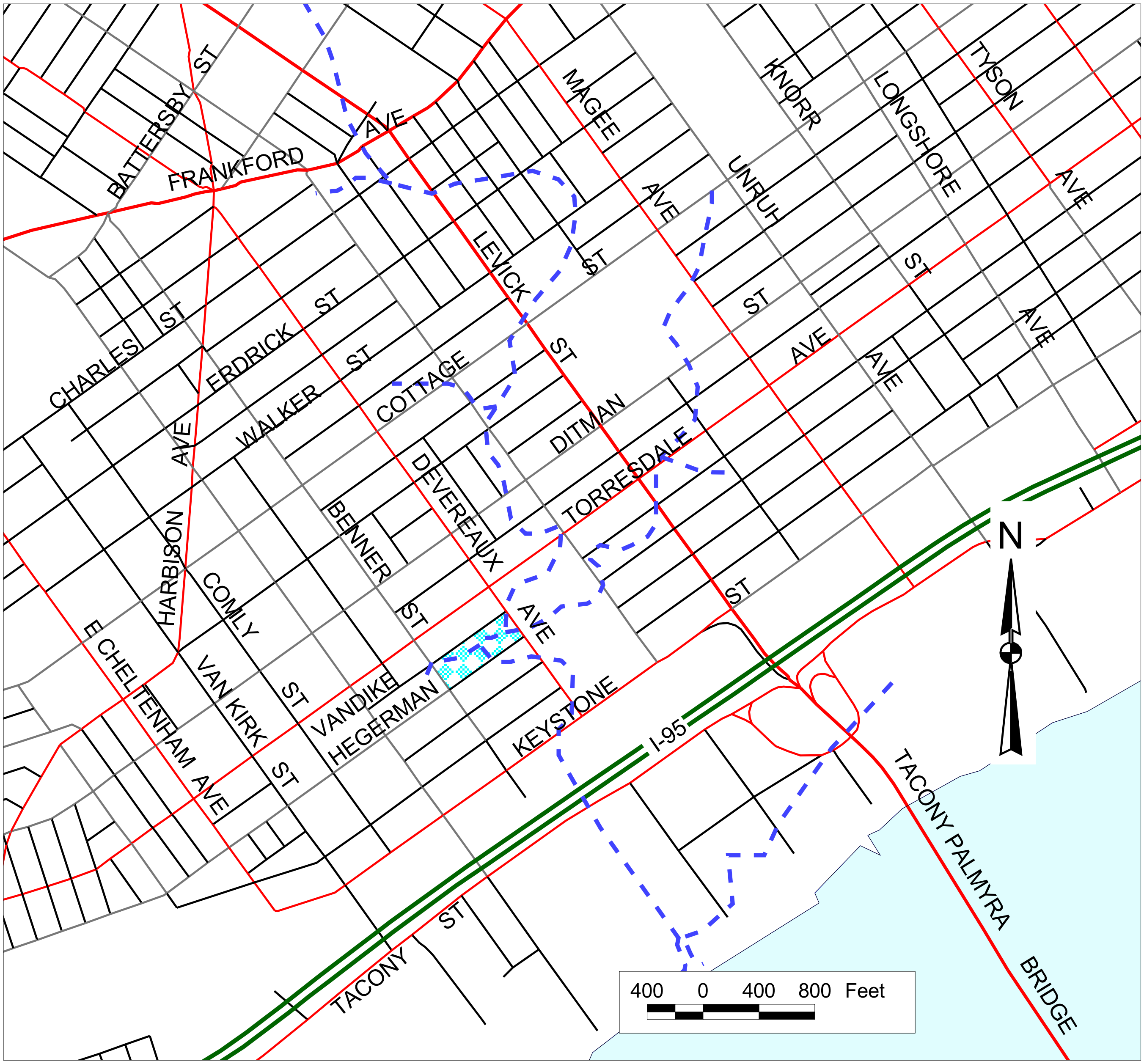
Tantala Associates, contracted by the City of Philadelphia, conducted a study on two of the buildings prior to demolition. Tantala concluded that the distress observed in the buildings was not related to the work associated with the installation of the sewer and water main. This conclusion was primarily based on the fact that records indicated that the residences had shown signs of distress almost immediately after they were constructed (Tantala 1999). Tanala went on to conclude that the homes were constructed directly above the confluence of the former Wissinoming Creek and one of its tributaries, which were eventually filled in and then developed. Furthermore, it appears that the former creek is now a subterranean watercourse and probably undermined the inadequately compacted fill material over time, which in turn caused settlement of the foundation walls of the buildings.

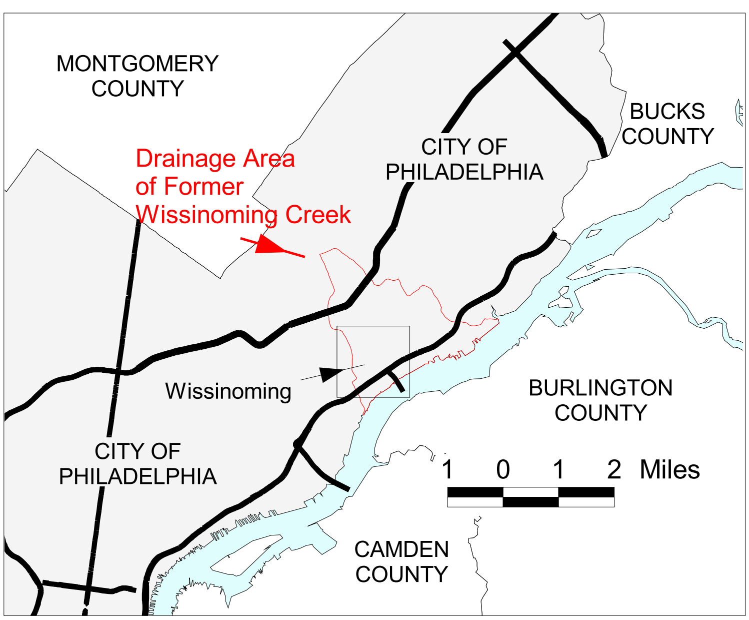
During the course of the Corps' investigation, the public provided additional information. Working under contract to the Water Department fifty years ago, a citizen recalled observing golf ball size pitting in the 93-inch diameter water main at the corner of Keystone Street and Devereaux Avenue. If pitting or other distress in this or any other water main continued, it may compromise the pipe and result in the washing away of loosely compacted material. Other citizens also mentioned that some row homes (on Devereaux Avenue between Edmunds and Tulip Streets and Unruh Avenue near Battersby Street) were built on piles, whereas the ones that failed nearby were not. Assuming that the piles were properly designed and founded in the native soil, bypassing the loose granular fill, the building would be expected to have considerably less settlement compared to building founded directly on the fill.

2.2 Scope of Study/Investigation

The City of Philadelphia, through Senators Specter and Santorum, and Representative Borski have requested the assistance of the US Army Corps of Engineers to gather and develop data as well as perform a preliminary analysis of the potential magnitude, extent, and scope of the problem and its possible causes. This investigation began by defining the horizontal and vertical extent of the original creek bed. Next, topographic change maps were prepared to show the distribution of fill by measuring topographical changes from a century ago. Limited geophysical investigations were performed in the basin to verify the location of the fill, characterize the soil conditions, and help ascertain the accuracy of the topographic change maps. Also, a cursory building exterior assessment was performed to identify any structures that were in imminent danger of failure, settlement and its correlation to the depth of fill, or if any structures had signs of continuing rapid settlement/movement. Lateral inspections have been performed on two homes which were adjacent to the demolished homes on Vandike and Hegerman Streets. Finally, drawings of water, gas, and sewer mains have been obtained from the City in various formats including hard copy and georeferenced digital images. Digital images of sewer lines have been incorporated into Geographic Information Systems (GIS) applications to support future investigations of these lines and their correlation to subsidence problems. This study presents findings and provides recommendations for more comprehensive studies required to design a remediation effort.

This is an environmental assistance project authorized by the Southeastern Pennsylvania Environmental Assistance Program, Section 566 of the Water Resources Development Act of 1996. Funding in the amount of $150,000 has been authorized to complete this initial engineering study in an effort to augment the on-going work of the City of Philadelphia and its private engineering/consulting firms.





VICINITY MAP

FORMER STREAM BED

AREA OF 1999
HOME DEMOLITIONS

STUDY AREA

SECTION 3.0
TOPOGRAPHICAL CHANGE MAP

3.1 US Army Corps of Engineers, Philadelphia District Map

3.1.1 Description of Work

For the Wissinoming area of immediate concern, the US Army Corps of Engineers, Philadelphia District was able to obtain detailed pre-development topography on which to base a higher resolution investigation of surface elevation changes.

The City of Philadelphia Streets Department provided maps showing five-foot contour intervals dating back to approximately 1888. The Corps scanned these maps and, using Arcview software, registered the resultant images to the City street grid. The contour lines were then digitized and appropriate elevation values assigned.

The 1888 five-foot contour lines were then overlaid on the City's current digital two-foot contour interval lines and a file created for all intersecting points of the two data sets. The 1888 elevation was compared to the current elevation at each point, thus indicating the net changes in ground elevations. The Arcview extension Image Analyst was then used to create a grid and a set of contours indicating the changes in elevations.

It is assumed that areas with a net increase in ground elevation have been filled sometime during the last century. As expected, areas showing the greatest increase in elevation - or depth of fill - are closest to the original course of Wissinoming Creek.

SECTION 4.0
EXISTING SUBSURFACE SOIL CONDITIONS

4.1 Geotechnical and Geophysical Investigations

4.1.1 Tantala Associates Study

Tantala Associates Consulting Engineers (Tantala) of Philadelphia, Pa., was retained by the City of Philadelphia, Office of the Director of Finance, Risk Management Division to conduct an inspection of the single-family dwellings at 6150 and 6152 Hegerman Street located in the Wissinoming section of Philadelphia. The purpose of the Tantala investigation was to determine the cause of distress in the building's front wall, with possible causal relationship between sewer reconstruction work in Hegerman Street, and whether the sewer reconstruction work accelerated, or contributed to, any previous and on-going distress in the building. In addition, the report provided recommendations possible remedial measures for the existing distressed structures and future analysis. Tantala submitted the results of their findings in their report dated 31 March 1999.

It was the professional opinion of Tantala, based on the knowledge and information available, that the distress observed in the buildings may have been attributed to the following:

- The row of buildings was probably constructed in an area where ash and cinder were used as fill material to raise the original grades to the current grade, and that most likely, the fill material was probably not compacted adequately, if compacted at all;

- The buildings inspected were constructed atop a former surface branch of the Wissinoming Creek and most probably exists as a subterranean watercourse.

- The subterranean branch of the watercourse may have undermined the loosely compacted ash and cinder fill material which in turn led to the settlement of the foundation walls causing the distress in the buildings.

It was also their opinion that the work associated with the reconstruction occurring along Hegerman Street between Benner Street and Devereaux Avenue did not contribute to the distress observed in the buildings. The report went on to recommend that the buildings be rebraced and shored, then demolished and replaced, and that comprehensive structural and subsurface investigations be conducted.

4.1.2 Tantala Associates Geotechnical Investigation

Following the demolition of a number of rowhouses in the area, Tantala conducted a separate subsurface investigation in order to obtain information for their building stabilization recommendations. The investigation was conducted in a portion of the Wissinoming section of Philadelphia bounded by Benner Street on the south; Hegerman Street on the east; Devereaux

Avenue on the north; and Torrsedale Avenue on the west. This area encompasses two city blocks that are separated by Vandike Street. This investigation was comprised of a total of 17 testing borings to determine the type, nature and state of the subsurface conditions. The drilling contract was executed by Ambric Testing and Engineering Associates, Inc., of Philadelphia, Pa., during the period 23-30 July 1999.

The test borings extended to depths ranging from 19 to 39 feet below the existing ground surface, at which point refusal was attained. Soil samples were taken with a 2-inch outer diameter split spoon using the Standard Penetration Test. Based on the drilling logs, it appears that sampling was not continuous, however, it was sufficient enough to characterize the layers encountered. Blow counts for the borings were recorded in six-inch increments and represent the energy imparted upon the soil by a 140 pound hammer free-falling 30 inches. All disturbed sampling was conducted in accordance with ASTM D 1586, “Penetration Test and Split-Barrel Sampling for Soils.” No undisturbed samples or rock cores were taken during this particular investigation.

No formal geotechnical report was submitted to the City of Philadelphia, however, all of the boring logs were submitted for review. No laboratory testing was conducted on the samples for either classification or strength determination. Instead, visual classification was performed in the field and the blow counts obtained from the standard penetration tests were used by Tantala in the design of their building stabilization that included auger-cast concrete piles on the newly exposed exterior walls and interior pipe piles. This stabilization was implemented at 6144 and 6145 Hegerman Street and 6127 Vandike Street.

4.1.3 US Army Corps of Engineers Geophysical Investigation

4.1.3.1 Background and Intent

A geophysical investigation was performed in the drainage basin of the former Wissinoming Creek in the Wissinoming, Tacony, and Mayfair neighborhoods of Philadelphia, Pennsylvania. The investigation was to identify the approximate location of the former Wissinoming Creek and determine the extent, depth, and where possible, the nature of the material used to fill the creek. Quantum Geophysics (Quantum) of Phoenixville, Pennsylvania conducted the fieldwork during the periods of 26-27 April and 18 May 2000. It should be noted that no drilling or sampling (geotechnical or chemical) was conducted by the Philadelphia District.

4.1.3.2 Contract Scope of Work

A scope of work was prepared and specified the use of ground penetrating radar (GPR) and electromagnetic (EM) methods to locate and delineate subsurface targets in the former valley of the Wissinoming Creek. Geophysical methods offer a noninvasive means of measuring subsurface characteristics. These methods, originally developed for fossil fuel and mineral exploration, have been successfully adapted to engineering/environmental applications. GPR measures changes in dielectric properties of subsurface materials and can delineate underground tanks/utilities, locate voids, and mapping of excavated areas. EM methods measure the bulk electrical conductance of the subsurface and can identify soil thickness variations and potential sinkhole development. (Further descriptions of these geophysical methods are provided in subsection 4.1.3.3 below). Based on the subsurface information available, namely from the borings obtained by Tantala, it was expected that the materials used to fill in the creek were likely to include cinders, ash, and construction debris. In addition, the density of the fill material should be significantly different than the density of the surrounding native sediments, i.e., looser. Thus, the goal of the geophysical survey was to determine the boundary between the miscellaneous fill and the native material. A map of the survey area is shown in Appendix B, page B1. The scope also included descriptions of lines to survey that were selected based upon an analysis of the thickness of the fill material (see Appendix B, page B2, Table 1).

4.1.3.3 Description of Geophysical Methods Employed.

4.1.3.3.1 Ground Penetrating Radar

Ground penetrating radar (GPR) is a subsurface exploration method that sends short duration, high frequency electromagnetic pulses from a transmitting antenna into the ground and records the reflected energy using a receiving antenna and a data recorder. Transmitting antenna frequencies range from 80 to 1000 megahertz (MHz), with 200 MHz and 400 MHz being the most commonly used. In general, the higher the frequency, the better the resolution of the subsurface reflectors, but the less the depth of penetration that can be achieved. The amount of imparted energy which returns to the receiving antennae is dependent on the materials encountered. Highly conductive materials such as clay, metals, and salt water attenuate the GPR signal and lead to poor or no data. Even small percentages of clay can rapidly increase attenuation of GPR signals, and limit its effective search depth.

4.1.3.3.2 Electromagnetic Induction/Ground Conductivity

Electromagnetic (EM) induction techniques measure the electrical properties of subsurface materials (or buried objects). An alternating current in the EM transmitter coil creates a magnetic field that induces electrical current loops within the ground. The current loops, in turn, create a secondary magnetic field. Both the primary magnetic field (produced by the transmitter coil) and the secondary field induce a corresponding alternating current in the EM receiver coil. After compensating for the primary field, the magnitude and relative phase of the secondary field can be measured. These can be converted to components in-phase and 90 degrees out of phase with the transmitted field. The out-of-phase component can be converted to a measure of apparent ground conductivity, which can be related to soil type, and the in-phase component can provide an indication of discrete, highly-conductive bodies such as buried metal objects.

4.1.3.4 Conduct of the Geophysical Investigation

Quantum laid out stationing on each of the survey lines using a 300-foot tape and orange spray paint. A spot was painted at each 50-foot mark, and total line distance was labeled at least every 200 feet. Two of the survey lines, the Levick Street line and the Vandike Street line, were broken into “A” and “B” lines due to high-traffic crossing points (Frankford Avenue and Levick Street, respectfully) that the geophysical survey equipment would not be able to traverse at a constant speed. Quantum then performed the ground penetrating radar survey on 26 April 2000 and the ground conductivity survey on 27 April 2000.

The GPR survey equipment consisted of one of two antennas towed behind an all-terrain vehicle mounted with a data recorder/monitor and battery (see Appendix B, page B3, Photos 1 and 2). The two antennas used were a 200 MHz Geophysical Survey Systems, Inc. (GSSI) model 5106 (serial number 2214) (see Appendix B, page B4, photo 3) and a 100 MHz GSSI model 3207A (serial number 130). Line survey control was entered by clicking a button when crossing every 50-foot distance mark, which enters a vertical line on the data record. Numerous passes were made on the first survey line attempted (the Erdrick Street line) in order to try out different gain levels and the two antennas. The 200 MHz antenna (owned by Quantum) provided good resolution, but only to a maximum depth of about 20 feet. The 100 MHz antenna should have provided moderate resolution but for deeper strata; however, the resultant records were indicative of either a concentration of GPR-absorbing clay material in the subsurface or a malfunction of the antenna. The 100 MHz antenna was tried on only one other line (the Devereaux Avenue line) and the same lack of response was received. Thus, only the 200 MHz antenna was used in completing the remainder of the GPR survey during the 27-28 April period.

The ground conductivity survey equipment consisted of a Geonics EM 31 ground conductivity meter system connected to a data logger (see Appendix B, page B4, photo 4). Since the EM 31 must be used away from all metal, the only line the survey could be performed on was in the park adjacent to the Devereaux Avenue line. Two 300-foot tapes were laid out parallel to the Devereaux Avenue line stationing in order to keep distance control. Data logger marks were entered every 10 feet during the ground conductivity survey (as opposed to every 50 feet as in the GPR survey).

Quantum returned to the site on 18 May 2000 with a different 100 MHz GPR antenna from an alternate source. This antenna was also a GSSI Model 3207A (serial number 057). Quantum re-surveyed all of the survey lines using this antenna, which responded with positive results. These results were utilized in the investigation, since the problem in April was the previous 100 MHz antenna, rather than the subsurface conditions. Apparent dipping reflectors could be seen in the data recorder display during the survey.

4.1.3.5 Results of the Geophysical Investigation

Quantum's report included results for the GPR and EM surveys. The Quantum report includes numerous odd-sized color plots of the GPR data, which are not included in this report. Instead, copies of both the report and the data plots are stored in the Philadelphia District office for future review, if necessary.

Analysis of the GPR survey results show three potential buried channels. Potential channels were seen at the following locations:

- Devereaux Avenue (from Keystone Street to Torresdale Avenue);
- Erdrick Street, about 500 feet from Magee Street toward Levick Street; and
- Calvert Street, about 470 feet from Tyson Street toward Friendship Street.

The locations of the potential channels are based on the interpretation of data by professionals within the USACE and Quantum Geophysics. All of the potential channels are between 50 and 100 feet wide and correspond with historic channel locations as mapped by the USACE. The GPR system could only penetrate approximately 15 feet with good resolution. Channels below this depth may exist but could not be detected with the GPR. The likely cause of loss of the radar signals is a moderate to high concentration of clayey materials in the subsurface. Based on the results of this investigation, it would be recommend that any future geophysical investigations in areas of similar soil types (predominantly clayey) should employ ground penetrating radar (GPR) only where subsurface targets are expected to be less than about 15 feet below the ground surface. If future geotechnical investigations, such as borings, indicate a lack of clayey material, then GPR could be tried in those locations.

Analysis of the electromagnetic (EM) survey, performed only in the park parallel to the Devereaux Avenue survey line, indicates a potential fill location extending 400 feet into the park from Keystone Street toward Torresdale Avenue. The park was the only location of the EM survey because the technology cannot be used in highly urbanized areas due to the numerous sources of metallic interference, such as utility lines. This area was characterized by relatively high readings, which indicate a clayey soil. This high conductivity was not seen in other portions of the Devereaux Avenue survey line and likely represents a lack of fill material. The electromagnetic method using the EM 31 ground conductivity meter cannot be used in highly urbanized areas due to the numerous sources of metallic interference to the method.

4.2 Subsurface Conditions

4.2.1 Geological Setting

The Wissinoming area of Pennsylvania lies along the edge of the Atlantic coastal plain geologic province. The coastal sediments in this area are diverse and related directly to fluvial systems draining to the sea. The Pennsauken and Cape May formations were deposited in the Wissinoming area and subsequently eroded by local streams. Today, these sediments can be found at higher elevations between the former Wissinoming and Tacony Creeks. They consist of poorly sorted sand and gravels. The erosive action of the former streams caused the early Paleozoic Wissahickon Formation to be exposed in the creek valleys. The Wissahickon Formation is widespread in Philadelphia and is the metamorphic by-product of originally interlayered sedimentary shales and sandstones. These sedimentary rocks were changed to schists and quartzites through intense temperatures and pressures. Marked cleavage, fissility, and coarsely crystalline texture are characteristic of the Wissahickon Formation. The engineering characteristics of the formation include abundant, well-developed platy cleavage and open steeply dipping irregular joints which are widely spaced. The schist is often highly weathered to a moderate depth.

4.2.2 Existing Subsurface Profile

Based on the drilling program conducted by Tantala, the materials encountered in the

Wissinoming section can be classified into three (3) different strata.

<u>Stratum 1 – Loose-to-Medium Compacted Miscellaneous Fill</u>

This layer was encountered in most of the borings taken over the site. The thickness of this layer ranged from ground surface to a depth of 14 feet. This stratum consists of ash and cinder mixed with varying amounts of building debris such as wood and bricks, and fine-grained soils (silt and clay). The fill material is characterized by low standard penetration resistance and the complete absence of a natural soil structure in the recovered samples.

Reportedly, this fill was placed in the early 1900's within the valley of the Wissinoming Creek that crossed the area at the time filling commenced in order to raise the ground to its current elevation prior to the development of rowhouses. The fill material is loose and apparently was placed with very little, if any, attempt to compact. Based on the nature of the fill, it is obvious that the filling operation was uncontrolled and that the nature of the fill varies tremendously across the site.

<u>Stratum 2 – Sand and Silt Layers</u>

Directly beneath the fill in most of the borings, and in other portions of the study area where ash and cinder were not present, several layers of silt, clay, sand, and organics were encountered. Generally, the layers of soil varied in thickness over the entire areal extent of the site and were found to be in a soft-to-medium state of consistency or a low-to-medium compact state of density. In some cases, thin layers of ash were encountered between layers of soil. This stratum was found to range in thickness from 9 to 24 feet. While some of the material may actually be native soil, it appears that fill material (other than ash, cinder or construction debris) may have been brought onsite. Due to the low compaction (as indicated by the low penetration resistance), the native and fill material may have been mixed and spread over the area as "common" fill material.

<u>Stratum 3 – Decomposed Mica Schist (Bedrock)</u>

A highly decomposed rock layer was encountered across the entire site directly beneath the fill or the residual soils. The deposit, which is the Wissahickon Formation, consists predominantly of hard green, brown, gray or black micaceous clayey silt with varying amounts of sand. Several layers of yellow and gray quartz were also identified within this layer. The materials exhibited the visual appearance of weathered rock, although they are essentially soil. The stratum was encountered at depths ranging from 11 to 29 feet below ground surface. All of the borings were terminated within this stratum at practical refusal to advancement of augers or the spoon sampler. No rock coring was attempted once refusal was achieved with the standard penetration sampling.

4.2.3 Groundwater

Groundwater was encountered in most of the borings at depths ranging from 9 to 27 feet below the existing ground surface, and these readings were taken during the drilling operation. Ground water levels are expected to fluctuate with daily and seasonal climatic changes. The groundwater surface appears to still slope downward along the original valley towards the old creek with the groundwater table depressed the greatest in the area of the creek.

SECTION 5.0
BUILDING EXTERIOR ASSESSMENTS

5.1 General

A visual assessment of the exterior of the structures in the Wissinoming area was made to determine the overall realm of the settlement problem, the seriousness of the problem, the potential for future catastrophic structural failure, and recommendations for future action. Visual exterior assessments provide valuable information on the extent of settlement and the condition of structures throughout a large area. Only limited conclusions, however, can be drawn without interior inspections of the foundation walls of individual structures, sewer laterals, and main sewer lines in streets. The age of the structures, which also reflects the type of design in this area, can influence the amount of information that can be gleaned from a visual inspection. The older row homes have more frame porches and dormers on the second floors that can obscure cracks in masonry. As structures age, owners use new, less expensive materials, such as various types of siding, to cover up aging or cracked masonry. Cracks in masonry are not necessarily caused by settlement, can be also be attributed to the aging process itself, a poorly designed mortar mix, or inferior brick, stone or concrete units. Even localized settlement can cause masonry or concrete steps to pull away from structures, but the structure itself does not have a settlement problem.

5.2 Limits of Assessment

The limits of the assessment were primarily determined by the former location, based on topographic mapping, of the Wissinoming Creek and its tributaries. The locations of the tributaries are no longer visible due to the filling of the stream valley and complete development of the area. South of Torresdale Avenue, the limits extended between Torresdale Avenue and Keystone Street and between Benner Avenue and Levick Street. North of Torresdale Avenue, the limits extended from Torresdale Avenue to Frankford Avenue and between Devereaux Avenue and Magee Avenue. These limits were determined using the original contours along the stream and observing the absence of any physical signs of distress from settlement. Generally, there where no signs in areas that had less than 10 feet of fill.

5.3 Description of Homes

A description of the residential structures is found in Section 2.0, Description/ Background of the Project. In addition to the structures described, there are commercial buildings and an apartment building located along Torresdale Avenue and commercial buildings located on the south side Frankford Avenue within the limits of the study area. The buildings on these two streets range from one story to three stories and are mostly masonry, but a few are frame construction. There are some individual buildings, but most were constructed in rows similar to the residential structures.

Some residential structures within the area have been converted to small retail stores, particularly the end units at the corners of blocks. A notable fact about the area is the existence of a common alley behind the homes or commercial buildings. The alleys are shared by two rows of structures back-to-back. They are paved and, for the most part, a large portion of the area between the structures is paved. Some structures have a small, unpaved yard, but all of them have a paved driveway that slopes down to single car garages that are located beneath the buildings. Generally, at each party wall there is a downspout(s) that conveys roof drainage and a small exterior drain in the pavement that picks up stormwater that flows down to the garage door and/or basement door opening. All of this flow is, collected and carried to a main sanitary sewer line or is tied into the sanitary sewer lateral laterals of the individual homeowners.

5.4 Assessment Criteria

Assessment of the building exteriors required walking along each street and alley to observe the structures for signs of distress that would indicate previous or continuing settlement problems. The greatest singular indicator of settlement is cracks that appear in masonry that are caused by differential settlement of a structure. Masonry, because of its inherent rigidity, cannot withstand the stresses created by settlement. Frame structures can withstand a much greater amount of settlement before the problems become evident. Distress in masonry caused by settlement is characterized by cracking that occurs along a line that is, generally, about 45 degrees to the vertical on a concrete face or stepped along joints of masonry units at about 45 degrees. This is related to the shear strength characteristics of mortar and concrete. The settlement cracks in masonry can occur anywhere, but usually originate from points of high stress concentration such as building corners or openings for windows and doors. Cracks that have been repaired and which continue to reopen are a good indicator that settlement is still occurring. Likewise, cracks that have been repaired in the past and now show signs of aging would indicate that settlement is not currently occurring. New crack repairs may also indicate settlement, but can also indicate replacement of old, weathered material.

Another indicator of settlement is any part of a structure (i.e., doorframe, garage door lintel, or windowsill) that is visually out of plumb or level. As a result, the exterior doors or storm windows are wracked or tilted and won’t close. Many times property owners cut doors to make them fit, which is apparent when looking at a structure. Exterior masonry chimneys that are out of plumb or separated from the main structure can also indicate settlement of a structure. Corners of buildings may be out of plumb due to settlement or just poor construction. In any type of assessment, experience and engineering judgment have to be used to evaluate the visual clues in determining if settlement is occurring.

5.5 Assessment Results

The structural assessment proceeded from the area that experienced the most serious problems, Vandike Street and Hegerman Street between Benner Street and Devereaux Avenue, and continued east along Vandike Street and Hegerman Street from Robbins Avenue to Levick Street. See Appendix C, page C15 for a map of the area inspected. The streets are not continuous and are separated by Lawton Playground, where some of the deepest areas of fill

(20ft.) are located. Then, the assessment continued northwest along a former main branch of the creek from Torresdale Avenue to Frankford Avenue, and north along a second branch from Torresdale Avenue to Magee Avenue. A cemetery is located along this branch between Ditman Street and Magee Avenue.

The structures on Vandike Street and Hegerman Street between Benner Street and Levick Street, of which all are two-story row homes, showed the typical signs of settlement, such as stepped cracks in the masonry, lintels out of level, and common party walls that have dropped. However, the number of signs per row of structures or per individual unit varied greatly from block to block and on the front or back of the structures. The signs generally correspond with the depth of fill and the location of the original streambed relative to its location on the block and to each structure assessed. Typically, the end wall of the last unit on a row exhibited the most evidence of distress caused by settlement. See Photo Nos. 1 through 4, Appendix C. The end units are most susceptible to the stress caused by settlement, because of the three sides that are free to move. End units serve as a buttress to the entire row of structures. For that reason, the City of Philadelphia bought two row homes, one at 6127 Vandike Street and the other at 6144 Hegerman Street (Photo No. 2), adjacent to the open area where the severely distressed homes were demolished. The foundation of the two homes was reinforced using pin piles, and the superstructure was tied together internally and externally using bolted steel angles and plates. This work was just recently completed and the homes are going to be sold "as-is" to new owners.

The most numerous signs of distress from settlement occurred on the rear of the row homes on the north side of Vandike Street between Benner Street and Devereaux Avenue (See Photo Nos. 8, 10, 11, 12, 13, 14, and 15, Appendix C), and the rear of homes on the south side of Vandike Street from Robbins Avenue to Levick Street. These homes had masonry with step cracks that were evident at wall openings and at corners, walls out of plumb, lintels out of level and common walls that have settled. There were, however, signs of distress from settlement along all of the rows of homes in the area. One particular home, located at the end of a row (4728 Levick Street, Photo No. 16, Appendix C) at the southeast corner of Levick Street and Vandike Street, had many cracks that were evidence of settlement. The cracks were repaired and the owner stated that he had purchased the home in that condition almost twenty years previously, and never had experienced any problems with windows, doors or level floors.

Commercial structures, apartment buildings, and some row homes along Torresdale Avenue from Benner Street to Levick Street showed no signs of distress on the front face and only minor cracks or tilting at one location on the rear face.

Structures in the area bounded by Torresdale Avenue north to Frankford Avenue and Devereaux Avenue to Magee Street showed signs of settlement at a minimal number of locations. These locations were the end units of row homes, where step cracks in the end walls or at the structure corners had been repaired. See Photo Nos. 5, 6, and 7, Appendix C.

A detailed list of the visual observations at each street address may be found in the Wissinoming Sinking Homes Structural Assessment trip report in the Appendix C.

SECTION 6.0
INFRASTRUCTURE

6.1 Existing Infrastructure

6.1.1 General

The Wissinoming area is a highly urbanized part of the City of Philadelphia and, as such, has a highly complex infrastructure that provides utility services to the residents. The underground utility lines are constructed in a grid pattern and form interconnected networks within the limits of the study area. Generally, the major underground utility lines are water, sewer, and gas. Maps and drawings of these lines have been obtained from the City in various formats including hard copy and georeferenced raster images.

The sewer lines within the area are a combined system that carries both sanitary sewage and storm water. Before being filled with varying natural/artificial materials, the Wissinoming Creek was encapsulated into a sewer system, which was installed at or near the location of the former creek. Remnants of this former creek, diverted through the infrastructure, ultimately discharge to the Delaware River. Raster images of sewer lines have been incorporated in Arcview projects designed to facilitate analysis of possible involvement of these lines in subsidence problems.

There are no underground electric lines except the lines that are located along Torresdale Avenue. At this time there are no reported underground communication or cable television lines. Similar to most large cities, the utility lines range from the newest to the oldest, with replacements occurring on an as needed basis as lines break and or as capital funds become available. All of the lines within the study area are subject to the stresses caused by the lack of a firm bedding due to settlement or loss of material under the pipes.

6.1.2 Water Lines

Water lines within the study area belong to the City of Philadelphia Water Department and they range in size from 6 inches in diameter to 93 inches in diameter. Similar to most distribution systems, the smaller side streets that serve the row homes have the smaller diameter (6 inch to 8 inch diameter) lines, and the larger diameter lines are located on the major streets. The lines are constructed of steel, cast iron, or ductile iron pipe. The cover on the pipes is generally 4 feet or greater, but there are exceptions where the cover is as shallow as 2 feet. The 93-inch diameter line, one of the largest lines in the city, is constructed of steel and is located along Keystone Street. It is reported to be at least 50 years old and possibly may be much older.

6.1.3 Gas Lines

Gas lines within the study area belong wholly to the Philadelphia Gas Works, which is a City of Philadelphia agency. The lines range from 6 inches in diameter to 20 inches in diameter, and are constructed of steel or ductile iron pipe. Generally, the 20-inch diameter lines are the high-pressure lines that feed the lower pressure 6-inch distribution lines. Service lines to individual structures are generally 4 inches in diameter or less. The cover is generally 3 feet but can vary to as little as 2 feet–8 inches. The lines are located either in the paved area of the street or the area beyond the curb line, but within the legal right-of-way line of the street.

6.1.4 Sewer Lines

As stated in Paragraph 6.1.1, all of the sewer lines within the study area are part of a combined sanitary/storm sewer system. The pipes are a multitude of sizes that range from 8-inch diameter circular pipes to an 11-foot by 13-foot rectangular box. Many of the older pipes, usually constructed of brick, were constructed as egg or ellipsoid shaped structures, with the long axis in the vertical plane. Similar to the pipe sizes, there is a multitude of pipe types depending on their age and size. The lines are constructed of terra cotta clay pipe (unfired), vitrified clay pipe (fired), brick, reinforced concrete circular pipe, and reinforced concrete rectangular box culvert type sections. The largest box culvert (11' x 13') generally follows the path of the old stream of Wissinoming Creek. The alignment, however, was designed to coincide with the center of the streets that were constructed subsequent to placement of the fill in the stream valley. This box flows south to the Delaware River. During periods of normal flow the combined sanitary/storm water flow can be can be treated as sanitary waste, but during periods of high flow, separating structures in the system were constructed with weirs to allow the excess flow to go directly into the river. The pipes have a large amount of cover because most of the lines are at the elevation of the existing stream valley and they flow by gravity to a lift station or treatment plant.

6.2 Infrastructure Observations

6.2.1 Laterals

Laterals are the connections from the house to the City sewer system and are privately owned and maintained by the individual homeowners. Two homes currently owned by the City, 6127 Vandike Street and 6144 Hegerman Street, were selected for lateral inspections because of their proximity to the previously demolished/condemned homes. The City purchased these homes because they were distressed, but did not demolish them because they provided some structural stability to the remaining homes adjacent to them. Philadelphia Water Department, Risk Management, and the Corps of Engineers were present to perform lateral inspections on these properties. The laterals were inspected using dye tests and a video camera made specifically for the interior of pipelines. Photographs of the lateral and sewer inspection are shown in Appendix D.

6.2.1.1 6127 Vandike Street

At the rear of the building, storm water from the roof and driveway flow into an underground drain in the vicinity of the party wall. This drain extends beneath the basement floor for tie-in with the building plumbing drain, then extends to the front of the property where rain water from the front porch roof previously tied in prior to exiting to the municipal sewer on Vandike Street.

Upon inspection, it was noted that the vertical vent pipe sections were misaligned with respect to each other. The lateral line was also filled with stone/gravel immediately upon entering the horizontal portion extending to the house. This is most likely the result of removal of the front porch drain which was currently being done during construction of a new block wall along the front sidewalk and side (extending to porch) of the property. It is believed that the soil entered the below grade opening during this construction period. The remaining pipe extending beyond this area underneath the building appeared intact. Access from the rear drain could not be obtained since the trap was clogged/blocked.

Inspection of the lateral from the sidewalk vent to the street sewer revealed that this portion of the line was completely broken/collapsed. The downstream portion after the break was mostly filled with mud and a void surrounded the opening. When a gallon of dye-colored water was put into the line, very little reached the sewer.

A large London Plane (Sycamore) tree was observed growing next to the vent. It is possible that the roots from this tree may have affected the lateral piping. No tree roots, however, were observed in the piping/openings.

6.2.1.2 6144 Hegerman Street

At the rear of the building, storm water from the roof and driveway flow into an underground drain in the vicinity of the party wall. This drain extends beneath the basement floor for tie-in with the garage sump drain and building plumbing drain, then extends to the front of the property where rain water from the front porch roof tie in prior to exiting to the municipal sewer on Hegerman Street.

Initial inspection of the property revealed that the rear drain was clogged, most likely a result of the soil which was placed to fill in the empty, adjacent lots where homes previously stood prior to their condemnation and subsequent razing in 1999. During the visit, storm water was observed draining beneath the concrete pad and at the corner where the garage door meets the party wall/foundation at the location of the rear drain. During a subsequent visit that was conducted during dry weather, an approximately 18-inch long hole (which extended further but was no longer visible) could be observed going underneath the garage floor downward and towards the front of the home.

After cleaning the rear drain, the camera could not pass through this portion of the drain so it could not be directly observed. It was not clear whether an obstruction existed, but it was proven that the line drained into the lateral by observing water flow downstream in the lateral that was coming from this source. Access to the lateral was obtained from the floor sump drain in the center of the garage. This portion of the line appeared to be intact until the tie-in to the newer VCP pipe was made. The new pipe was both cracked and misaligned at this connection. The remaining sections that could be filmed from this route showed pipe misalignments and possible separations at the joints.

The vent pipe at the sidewalk also showed several misaligned sections where soil was permitted to enter and a cracked section of pipe. The lateral toward the house displayed similar features –

misaligned pipes with separations and downward drops that may indicate undermining and/or improper installation.

6.2.2 Sewers

6.2.2.1 Vandike Street

The Philadelphia Water Department and Risk Management performed an examination of the 27 by 18-inch brick and mortar sewer between Benner Street and Devereaux Avenue. The sewer appears to have no structural defects within the limits of inspection.

6.2.2.2 Hegerman Street

The Philadelphia Water Department and Risk Management performed an examination of the 72-inch reinforced concrete sewer in the vicinity of 6144 Hegerman Street. The sewer appears to have no structural defects within the limits of inspection. No problems were suspected as the sewer main on this street was completely replaced in 1997.

SECTION 7.0
CONCLUSIONS

7.1 USACE Topographical Change Map

The topographic change maps completed by the USACE, utilizing detailed pre-development topography, provided a high resolution investigation of surface elevation changes for smaller, localized region. This map assisted in defining the depth and extent of the fill in the vicinity of the disaster and assisted in focusing the areas of investigation for further subsurface and building assessment investigations. The map is depicted in Appendix A.

7.2 Subsurface Investigations

7.2.1 Geotechnical Investigation

Based on the results of previous and current investigations, it appears that the former Wissinoming Creek has been filled in with a combination of “common” and miscellaneous fill. Within the area were the rowhouses were condemned and razed, the “common” fill ranges in thickness from 9 to 24 feet and is comprised of layers of sands, silts, clays and organics. Some of the layers may be native to the area, coming from the decomposition of the mica schist bedrock that underlies the entire area, however, it appears that it may have been mixed with other material not native to the area, to partially fill in the creek. Because of the low penetration resistance, this fill appears not to have been properly compacted (to today’s standards). The miscellaneous fill is comprised of ash and cinders mixed with varying amounts of construction debris, such as wood and brick, and soil. This type of fill is similar to that encountered in other areas of Philadelphia such as Logan and Feltonville Sections. The depth of miscellaneous fill encountered in the Wissinoming Section varies from ground surface to 14 feet. Again, these depths are representative in the area where geotechnical investigations were conducted. This layer of ash and cinder also has a low penetration resistance and, as was the case for the “common” fill, it appears that the filling was not controlled and adequate compaction (again, to today’s standards) was not achieved.

The investigations of the Logan Section of Philadelphia, conducted by Lippincott Engineering Associates (1986, 1987), have confirmed that loosely compacted ash and cinder fill is not an ideal foundation material, and its unique physical properties make it susceptible to excessive settlement with changes in conditions. The most prevalent is the presence of water. Some properties, and the effects of water include, but are not limited to, the following:

- The densification by ponding (e.g., the accumulation of water) or compaction could result in a volumetric change in the ash. This would result in the fill changing from a loosely compacted state to a more compacted state, and with the decrease in volume there would be an increase in settlement. If the settlement is not uniform over an area, this leads to differential settlement which may have significant impacts on the structural integrity of a building.

- The shear strength of the ash and cinder is typical to that of a loose granular material. Generally, the shear strength of saturated granular soils is about the same as the shear strength of dry granular soils (at a given state of compaction). However, tests run on similar materials obtained in the Logan Section, indicated a significant decrease in the shear strength of ash and cinder when saturated.

- The elastic settlement characteristics of the ash and cinder are typical of granular material. Elastic, or “immediate,” settlement of a foundation takes place during or immediately after the construction of the structure. All structures undergo elastic settlement. The amount of elastic settlement that can occur is dependent upon several parameters including the stress increase at the foundation level, the thickness of the soil layer(s) and the modulus of elasticity of the soil(s). Since the material is not cohesive, it does not undergo consolidation (which is the dissipation of excess pore water pressure in silty and clayey deposits that result in settlement over time).

- Ash and cinder are highly susceptible to dispersion and piping. Piping is the condition where the finer-grained particles are carried away with the water through the larger pores in the soil matrix.

- Ash could be lost by either dissolving or by being carried away in migrating water with a higher amount when in an acidic environment. An example of this is when laterals crack or rupture and the flow of water and or wastewater flushes material away. The crack in the lateral also provided a conduit for the material to leave. This condition can be exasperated when wastewater is introduced, because of the lower pH (more acidic), the ash may dissolve.

- The permeability of the material is similar to granular material of the same grain size.

Combined with the exterior structural investigation conducted, it appears that the majority of the settlement exhibited by the residences in the Wissinoming Section is due to the elastic settlement of the granular materials used to fill in the former creek. These homes were situated on a combination of loosely compacted miscellaneous and “common” fill placed in the former valley of the Wissinoming Creek. By today’s standards of suitable foundation materials and compactive efforts, these materials would be unacceptable. Current standards would require a quality structural fill, such as well-graded sand with little to no fines, with specifications for compacted density, moisture content and placement thickness.

The amount of elastic settlement that can occur is highly dependent on the modulus of elasticity of the soil, e.g., the lower the modulus, the higher the settlement. Empirical correlations have also been made comparing modulus with the number of blow obtained during the standard penetration tests and show that the values are directly proportional. Based on the low penetration resistance observed in the test borings completed by Tantala, it can be concluded that the fill used in the area has a low modulus and most likely resulted in amounts of elastic settlement which exceeded the tolerable amounts that are normally accepted today, but do not make the structures unsafe or unsound.

The presence of water in the loosely compacted fill material can lead to additional settlement beyond that which occurs immediately. The lowering of the groundwater table, which can happen either naturally over time or by methods such as pumping (dewatering operations), increases the stress that is imposed on the soil structure and thereby the amount of settlement that can occur. The rising of the groundwater table can also affect loose, granular material by allowing the soil particles to settle in a denser orientation. Subsurface erosion due to the flow of the groundwater and/or the introduction of water from house laterals or street sewers could possibly occur.

With the information known regarding the physical properties of the miscellaneous fill and the investigation conducted by Tantala, it appears that the construction activities associated with the replacement of the sewer main on Hegerman Street may have had an effect on some of the buildings in the vicinity. The combination sewer installed during the construction was a 72-inch diameter, reinforced concrete pipe that was buried approximately 18 feet deep. The entire street, including both sidewalks and laterals, were also replaced. Feasibly, the introduction of water and dewatering operations may have deleteriously affected the fill in the area were the main was being repaired/replaced.

7.2.2 Geophysical Investigation

The ground penetrating radar (GPR) survey was unable to clearly identify buried channel boundaries in all of the areas the channels were expected to be located. Potential buried channels were detected in three of the eight survey lines. Despite attempts to optimize penetration depth and resolution by varying the antenna frequency and other electrical parameters, adequate penetration depth with good resolution could not be achieved in order to delineate the buried channels of the former Wissinoming Creek and its tributaries. The following are possible reasons for this situation:

- The subsurface materials are too clayey, thus inhibiting GPR signal return.

- The fill material(s) and the adjacent native sediments are too similar in electrical properties to be distinguished from one another.

- The survey line locations pre-selected by Philadelphia District personnel from analysis of topographic comparison did not cross the buried channels.

- The GPR technology is inadequate to resolve buried channels at depths below approximately 15 feet.

- The GPR survey contractor was unable to employ the GPR method to satisfactorily identify the buried channels.

It is less likely that the selected survey lines did not cross the creek since field observations indicate that the survey lines cross current topographic lows, which likely align with the original topographic lows. It is also less likely that the GPR technology cannot resolve buried channels at depths below 15 feet or that the experienced GPR survey contractor was unable to employ GPR to identify the buried channels. Finally, the density of the fill material(s) should be significantly less than the density of the adjacent sediments such that an approximate boundary could be identified using GPR. Thus, it is concluded that the GPR signal was attenuated by high clay content in the subsurface materials, causing a lack of resolution below approximately 15 feet.

The electromagnetic survey was able to identify a potential buried channel in the park parallel to the Devereaux Avenue survey line. Unfortunately, the method could not be used on any of the other survey lines due to interference from metallic sources such as fences, vehicles, metal pipes, and other metallic items in the urban environment.

7.3 Building Exterior Assessments

All of the structures visually assessed currently appear in stable condition. There was no evidence of continuing settlement. The structures south of Torresdale Avenue on Vandike Street and Hegerman Street showed more signs of distress from settlement along entire rows of structures, while the structures north of Torresdale Avenue showed signs of distress from settlement at the end units of rows of structures. At some locations, downspouts were adjacent to walls that appear to have settled, but that they were the direct cause of settlement can not be definitely concluded without further investigation.

7.4 Infrastructure

7.4.1 Laterals

The laterals are located at a depth which places them within the fill layer. As the fill compacts, the laterals settle and the joints open further.

Water and sewer lines, if defective, provide a means for fill material to either wash away in the flow of a sewer or densify the fill by and/or wash the fine particles away. The volume of the supporting fill is then reduced, leading to further settlement. Both homes left standing immediately adjacent to the demolished homes showed signs of misaligned and separated pipes which contribute to the problem described above. The pipe used in the installations can separate since the end of one pipe is merely fitted into the bell mouth of an adjoining pipe. Portions of the pipes serving both homes were cracked, one portion completely collapsed. Each home also had portions of the line filled with soil/gravel.

On Vandike Street, misalignment of the pipe could possibly be attributed to the roots from large trees which line the street. Otherwise, the misalignment can result from either undermining of the soil surrounding the pipe and/or poor construction practices. Rainwater, if allowed to collect and drain in only concentrated areas, also begins to densify/wash fine particles to form channels beneath the surface. When a rear drain was clogged, water quickly drained into cracks beneath the driveway and the foundation, forming a channel. Evidence of this could also be seen along the older sidewalks on Vandike Street, where cracks in sidewalks opened to eroded, hollow spaces beneath.

7.4.2 Sewers

An examination of the original brick and mortar sewer on Vandike Street between Benner Street and Devereaux Avenue and a portion of the newly installed sewer on Hegerman Street did not reveal any structural defects.

SECTION 8.0
RECOMMENDATIONS

8.1 Topographical Change Map

- Utilizing Streets Department data, analyze and provide more detailed, localized depth of fill maps for all of Wissinoming to include completion of data digitization for water, gas, and sewer.

8.2 Geotechnical Considerations

- Based on the information obtained during the structural assessments, there is no need to conduct any additional geotechnical or geophysical investigations outside of the portion of the Wissinoming section where the residences were condemned and demolished. Tanala Associates conducted their subsurface investigation within that section and were able to determine the depth and nature of the fill, thereby eliminating any further investigation in that portion of Wissinoming.

- Any new buildings that may be constructed in the former valley of the Wissinoming Creek should be founded on suitable ground. Several options are available such as deep foundation systems and ground modification techniques to either bypass the problem soil or to improve it into a more suitable foundation material. The use of a deep foundation system, such as piles, could extend below the depth of the fill and be situated on native material, namely the decomposed bedrock of the Wissahickon Formation. Ground modification techniques, such as grouting and vibrocompaction, where the existing soil is mixed with cementitious materials (grouting) or is densified (vibrocompaction) to improve the physical and engineering properties of the soil could be considered. Further subsurface investigations would be required in order to assess the most feasible and economical method, and a registered professional engineer should perform any necessary foundation design.

- Ideally, all of the utilities should be founded in competent material. During the replacement or repair of any utilities in the Wissinoming neighborhood that may be founded on fill material, the City should ensure that the utilities are set and backfilled with compacted structural fill.

- If any future construction or remedial action is undertaken by the City of Philadelphia, issues regarding potentially contaminated soil should be addressed, namely for health and safety reasons. It is important to note that the District is not implying that there are any elevated levels of contaminants in Wissinoming. There are currently no health hazards because there is no direct contact with the fill material. Should any future excavation occur however, chemical sampling and testing should be conducted prior to incorporate the appropriate safety measures.

- Future geophysical investigations in areas of similar soil types (predominantly clayey) should employ ground penetrating radar (GPR) only where subsurface targets are expected to be less than about 15 feet below the ground surface. If future geotechnical investigations, such as borings, indicate a lack of clayey material, then GPR could be tried in those locations.

- The electromagnetic method using the EM 31 ground conductivity meter cannot be used in highly urbanized areas due to the numerous sources of metallic interference to the method.

8.3 Building Exterior Assessments

- Perform an inventory of the structures that show signs of distress caused by settlement within the fill area.

- Perform a semi-annual or annual inspection to update or supplement the inventory. Any structures showing signs of continuing or rapid change should be inspected more thoroughly, including interior foundation walls. A map of the homes which lie within the fill area is located in Appendix C, page C16.

- Establish a telephone number for residents to call if they notice changes in their particular structures.

- Establish a standard procedure for which a detailed structural inventory would be performed and damage prevention measures would be instituted at locations where construction activities (i.e. deep excavations, dewatering, pile driving, fill compaction etc.) are undertaken that might disturb the fill.

- Establish survey reference points on structures that show the most signs of settlement, particularly the structures at the end of rows, and monitor the movement annually by field survey. The reference points would be benchmarks (such as pins installed in the walls) that would facilitate settlement measurement (if any) over time.

- Inspect rainwater conductors to ensure integrity/proper drainage at the downspouts; repair and replace as necessary.

8.4 Infrastructure

- Philadelphia Water Department to inspect sewer and water infrastructure in areas of fill to verify integrity; repair if necessary.

- Inspect homeowner laterals in areas of fill to ensure integrity/proper drainage; repair and replace as necessary (possibly using alternate materials such as PVC piping).

- Investigate impact of large trees from sidewalks which could be impacting sewer/lateral integrity; remove/replace with a variety less conducive of damage.

SECTION 9.0
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SECTION 10.0
APPENDIX